

Earth Radiation Budget Experiment (ERBE) for Monthly Medium-Wide Data Tape (MWDT) (S-7) Langley ASDC Data Set Document



Summary:

This document describes the monthly Medium-Wide Data Tape (MWDT) (S-7) and provides the user with the necessary information to use these Earth Radiation Budget Experiment (ERBE) data for scientific research studies.

The S-7's name, Medium-Wide Data Tape, includes the word "tape", since the original intent was to maintain and distribute this product only as a magnetic tape. Though this is no longer the case, the original name is being maintained to ensure consistency throughout the ERBE software and documentation systems.

Table of Contents:

1. [Data Set Overview](#)
2. [Investigator\(s\)](#)
3. [Theory of Measurements](#)
4. [Equipment](#)
5. [Data Acquisition Methods](#)
6. [Observations](#)
7. [Data Description](#)
8. [Data Organization](#)
9. [Data Manipulations](#)
10. [Errors](#)
11. [Notes](#)
12. [Application of the Data Set](#)
13. [Future Modifications and Plans](#)
14. [Software](#)
15. [Data Access](#)
16. [Output Products and Availability](#)
17. [References](#)
18. [Glossary of Terms](#)
19. [List of Acronyms](#)
20. [Document Information](#)

1.Data Set Overview:

Data Set Identification:

ERBE_S7_NAT: Earth Radiation Budget Experiment (ERBE) S-7 Monthly Medium-Wide Data Tape in Native (NAT) Format

Data Set Introduction:

The MWDT (S-7) product contains a condensed version of the nonscanner data that are found on a monthly set of Processed Archival Tapes (PAT), **except** that the shortwave estimates of the radiant exitance at the top-of-atmosphere (TOA) are based on the mostly-cloudy over ocean bidirectional model (see MWDT (55-62)). The MWDT product then provides a consistent data set of nonscanner TOA estimates which are not dependent on the operational status of the ERBE scanner instruments.

Objective/Purpose:

The objectives of the ERBE are:



1. To determine, for a minimum of 1 year, the monthly average radiation budget on regional, zonal, and global scales.
2. To determine the equator-to-pole energy transport gradient.
3. To determine the average diurnal variation of the radiation budget on a regional and monthly scale.

Summary of Parameters:

The MWDT (S-7) product contains a condensed version of the nonscanner data that are found on a monthly set of Processed Archival Tapes (PAT) (see S-8 product), **except** that the shortwave estimates of the radiant flux at the top-of-atmosphere (TOA) are based on the mostly-cloudy over ocean bidirectional model. The MWDT product then provides a consistent data set of nonscanner TOA estimates which are not dependent on scene type and, therefore, not dependent on the operational status of the ERBE scanner instruments. The filtered nonscanner radiometric values are 4-second averages on the MWDT, as opposed to 0.8-second measurement values on the PAT. The MWDT contains no scanner data. Each MWDT product contains data for one month and from one spacecraft. The month is divided into daily data sets, each of which are divided into 16-second records. Each record contains the following:

- Time in Julian day
- Spacecraft position and velocity
- Sun position
- 4-second averaged medium and wide FOV (field of view) radiometric measurements in Wm^{-2} (total, shortwave)
- 4-second averaged medium and wide FOV unfiltered measurements in Wm^{-2} (shortwave, longwave)
- 32-second estimate of radiant flux at the TOA from nonscanner measurement

Discussion:

The goal of ERBE is to produce monthly averages of longwave and shortwave radiation parameters on the Earth at regional to global scales. Preflight mission analysis led to a three-spacecraft system to provide the geographic and temporal sampling required to meet this goal. Three nearly identical sets of instruments were built and launched on three separate spacecraft. These instruments differ principally in the spacecraft interface electronics and in the field-of-view limiters for the nonscanner instruments required because of differences in the spacecraft orbit altitudes.

The ERBS spacecraft was launched by Space Shuttle Challenger in October 1984 and was the first spacecraft to carry ERBE instruments into orbit. The ERBS was designed and built by Ball Aerospace Systems under contract to NASA Goddard Space Flight Center (GSFC), and ERBS was the first spacecraft dedicated to NASA science experiments to be launched by the Space Shuttle. The ERBS carries the Stratospheric Aerosol and Gas Experiment II (SAGE II) in addition to the ERBE instruments. The Payload Operation and Control Center (POCC) at GSFC directs operations of the ERBS spacecraft and the ERBE and SAGE II instruments, employing both ground stations and the Tracking and Data Relay Satellite System (TDRSS) network. Spacecraft and instrument telemetry data are received at GSFC where the data are processed by the Information Processing Division that provides ERBE and SAGE II experiment data to the NASA Langley Research Center (LaRC).

The second and third spacecraft launched with ERBE instruments are Television Infrared Radiometer Orbiting Satellite (TIROS) N-class spacecraft, which are part of the NOAA operational meteorological satellite series. The NOAA-9 and NOAA-10 spacecraft were launched in December 1984 and September 1986, respectively. The NOAA spacecraft includes other instruments, such as the Advanced Very High Resolution Radiometer (AVHRR) and the High-Resolution Infrared Radiometer Sounder (HIRS), which provide NOAA with data for near-real-time weather forecasting. Both spacecraft are in nearly sun-synchronous orbits. The equator-crossing times (at launch) of the orbital nodes for the NOAA-9 and NOAA-10 orbits were 1420 UT (ascending) and 1930 UT (descending), respectively, where UT denotes universal time. The Satellite Operations and Control Center (SOCC) at the National Environmental Satellite and Data Information Service (NESDIS) operates the NOAA spacecraft. NOAA also provides demodulation processing of the telemetry data and generates ERBE data for LaRC.

NASA tracks the ERBS spacecraft, and the North American Aerospace Defense Command (NORAD) tracks the NOAA spacecraft. The tracking data are provided to GSFC where orbit ephemeris data are calculated for all three spacecraft and provided to LaRC.

Related Data Sets:

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2. Investigator(s):

Investigator(s) Name and Title:



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<http://eosweb.larc.nasa.gov>



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Title of Investigation:

Earth Radiation Budget Experiment (ERBE)

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3. Theory of Measurements:

The theory behind the measurements made to collect the ERBE data is non-trivial and well beyond the scope of this document. However, interested readers are referred to the following publications: NASA Reference Publication 1184, Vol I and II; NASA Technical Paper 2670; and Smith *et al* at ([Reference 12](#)).

4. Equipment:

Sensor/Instrument Description:

Collection Environment:

All three sets of ERBE instruments were designed to collect data for one year but had a goal of two years. The nonscanner instruments continue to collect data for ERBS; however, the nonscanner instruments on-board NOAA-9 and NOAA-10 have been deactivated. Table 1 describes the nominal orbit parameters for each satellite at launch.

Table 1. Nominal Orbit Parameters for Each Satellite at Launch

Nominal Orbit Parameter	ERBS	NOAA-9	NOAA-10
Launch Date	October 5, 1984	December 12, 1984	September 17, 1986
Planned Duration	1 Year	1 Year	1 Year
Actual Duration Scanner	5-1/2 years (February 28, 1990)	3 years (January 20, 1987)	2-1/2 years (May 22, 1989)
Actual Duration Nonscanner	Operating	Over 12 years, deactivated April 3, 1997	Over 8 years, deactivated December, 1994
Orbit	Precessing	Sun-synchronous	Sun-synchronous
Semi-major Axis	6988 km	7248 km	7211 km
Mean Altitude	610 km	872 km	833 km
Inclination	57 deg	98 deg	98 deg
Nodal Period	98 minutes	102.08 minutes	101.2 minutes
Equator Crossing Time (at launch)	Variable	1430 Local Mean Solar Time, ascending	0730 Local Mean Solar Time, descending

Source/Platform:

The ERBE instruments are on the ERBS, NOAA-9, and NOAA-10 satellites.

Source/Platform Mission Objectives:

ERBS was the first spacecraft dedicated to NASA science experiments to be launched by the Space Shuttle. ERBS carries SAGE II instruments in addition to the ERBE instruments. The NOAA spacecraft include other instruments, such as the Advanced Very High Resolution Radiometer (AVHRR) and the High-Resolution Infrared Radiometer Sounder (HIRS), which provide NOAA with data for near-real-time weather forecasting.

Key Variables:

A complete list of the measured parameters is found in Table 2.

Table 2. ERBS, NOAA-9, and NOAA-10 ERBE Detector Characteristics

	CHANNEL	WAVELENGTH LIMITS (microns)	MEASUREMENT
Nonscanner Fixed Wide field of view	1	0.2-50.0	Total Radiance
	2	0.2 - 5.0	Shortwave Reflected
Nonscanner Fixed Medium field-of-view	3	0.2 - 50.0	Total Radiance
	4	0.2 - 5.0	Shortwave Reflected
Fixed Solar Monitor	5	0.2 - 50.0	Total Irradiance
Scanner Narrow field-of-view	1	0.2 - 50.0	Total Radiance
	2	0.2 - 45.0	Shortwave Reflected
	3	5.0 - 50.0	Longwave Emitted

Principles of Operation:

ERBE is a multisatellite system designed to measure the Earth's radiation budget. The ERBE instruments fly on a mid-inclination NASA satellite (Earth Radiation Budget Satellite (ERBS)) and two two-synchronous National Oceanic and Atmospheric Administration (NOAA) satellites (NOAA-9 and NOAA-10). Each satellite carries both a scanner and a nonscanner instrument package.

The scanner instrument package contains three detectors to measure shortwave (0.2 to 5 microns), longwave (5 to 200 microns) and total waveband radiation (.2 to 200 microns) ([Reference 1](#)). Each detector scans the Earth perpendicular to the satellite groundtrack from horizon-to-horizon. The detectors are thermistors which use space views on every scan as a reference point to guard against drift. They are located at the focal point of an f/1.84 Cassegrain telescope, whose aluminum-coated mirrors have been overcoated to enhance ultraviolet reflectivity. The total channel has no filter and so absorbs all wavelengths. The shortwave channel has a fused silica filter which transmits only shortwave radiation. The longwave channel has a multilayer filter on a diamond substrate to reject shortwave energy and accept longwave. To enhance the spectral flatness of the detectors, each thermistor chip is coated with a thin layer of black paint. The instantaneous field-of-view (FOV) of each channel is hexagonal, with an angular size of 3 degrees by 4.5 degrees; the longer dimension being along the satellite groundtrack.

The nonscanner instrument package contains four Earth-viewing channels and a solar monitor ([Reference 2](#)). The Earth-viewing channels have two spatial resolutions: a horizon-to-horizon view of the Earth, and a field-of-view limited to about 1000 km in diameter. The former are called the wide field-of-view (WFOV) and the latter the medium field-of-view (MFOV) channels. For each of the two fields of view, there is a total spectral channel which is sensitive to all wavelengths and a shortwave channel which uses a high purity, fused silica filter dome to transmit only the shortwave radiation from 0.2 to 5 microns. The solar monitor is a direct descendant of the Solar Maximum Mission's Activity Cavity Radiometer Irradiance Monitor detector. Because of the concern for spectral flatness and high accuracy, all five of the channels on the nonscanner package are active cavity radiometers.

Sensor/Instrument Measurement Geometry:

The nonscanner elevation beams can be rotated to any of three positions: launch/stow/internal calibration position (180 degrees), solar calibration position (78 degrees), and Earth-viewing (nadir) position (0 degrees). The WFOV detectors view the Earth from limb-to-limb (plus a small ring of space). The MFOV detectors are designed to include approximately an Earth view of 10 geocentric degrees within the unencumbered field of field (FOV).

The scanner can rotate in azimuth between 0 degrees and 180 degrees with an accuracy of 0.075 degrees. The normal scan mode is cross-track. The effective FOV of the scanner is 3 degrees.

Manufacturer of Sensor/Instrument:

The ERBE instruments were developed by TRW, Inc.

Calibration:

Specifications:

Specifications are currently unavailable.



Tolerance:

The tolerance is 1 percent for the total channel and 2 percent for the shortwave channel.

Frequency of Calibration:

For the scanner instruments, in-flight calibrations were accomplished every scan, as well as on a bi-weekly basis. In-flight calibrations of the non-scanners were normally performed on a bi-weekly basis.

Other Calibration Information:

The ERBE instruments were developed by TRW, Inc. Laboratory calibrations of the ERBE non-scanner and solar monitor instruments were completed in the TRW calibration facility at Redondo Beach, California in 1984. The fundamental standards used for the ERBE instruments were the International Pressure and Temperature Standard of 1968 (IPTS-68) and the World Radiation Reference (WRR). The TRW master reference blackbody (MRBB) was calibrated using these, and the MRBB was subsequently used to transfer the calibrations to the internal blackbody (IBB) and to the shortwave channels via an integrating sphere. The results of the calibrations were reported in detail in TRW calibration documents.

In-flight calibrations are performed in order to maintain the accuracy of radiometric measurements by accounting for internal instrument component parametric changes brought about by the spacecraft's environmental variables. In-flight calibrations of the non-scanners were normally performed on a bi-weekly basis. These included internal calibrations, space looks, and solar calibrations. Internal calibrations consist of cycling of IBB temperatures (total sensors) and shortwave internal calibration source (SWICS) voltages. Space looks consist of observations of "cold" space, both before and after solar calibrations. Solar calibrations consist of measurements made while the solar disc is within the instrument's FOV.

On days when internal calibrations are performed, shortwave offsets are independently determined in four ways:

1. The preferred offsets are determined by using the aggregate of all earth-viewing data taken when the solar zenith angle is greater than 123 degrees, and assuming that the shortwave radiance is zero. Because of the solar zenith angle requirement, it is not always possible to use this method.
2. The second choice offsets are determined by using the data acquired during the internal calibration period, with the SWICS-off. Again it is presumed that the shortwave radiance is zero.
3. The third choice offsets are determined using data acquired during the so-called "B-soak" period which occurs before every internal calibration sequence is begun. During this period, all of the sensors are exposed to their respective calibration sources, but all power to the sources is off.
4. The fourth choice offsets are determined from the (approximately 30) samples of "cold" space which occur between the solar disk observation and the re-capture of the earth disk.

In cases where the first option is not viable, the second option is used, along with a linearly-fitted delta based upon the historical differences between method 1 and method 2. The offsets determined using options 3 and 4 have never been used in production processing.

5. Data Acquisition Methods:

The ERBE non-scanner instrument consists of four Earth-viewing detectors and one solar monitor detector located on the head assembly. The four Earth-viewing detectors are unchopped active cavity radiometers (ACR), whereas the solar monitor is an unfiltered chopped ACR designed to measure direct solar radiation for calibrating the Earth-viewing detectors. Two of these detectors have wide field-of-view (WFOV) apertures allowing the detectors to view the entire disk of the Earth; the other two detectors have medium field-of-view (MFOV) apertures allowing the detectors to view an area about 1000 km in diameter. Two of the Earth-viewing detectors, one WFOV and one MFOV, and the solar monitor detector measure total radiation, whereas the other two Earth-viewing detectors measure shortwave radiation. The total radiation detectors are unfiltered, and the shortwave spectral bands are achieved by use of fused silica dome filters placed over the detectors.

The non-scanner instrument microprocessor processes and executes ground-commanded and stored commands to direct and control the instrument operations. The instrument can operate in several modes so that radiation measurements can be made over a wide range of operational conditions. The instrument can operate at azimuth angles between 0 and 180 degrees, and at fixed elevation beam positions of 0 (nadir), 78 (solar ports), and 180 (stow or internal calibration position) degrees. Normal Earth-viewing operation is at the nadir elevation position and at an azimuth position of 180 degrees for NOAA-10, 170 degrees for NOAA-9, and 0 degrees for ERBS. The ERBE non-scanner instrument output consists of a complete cycle of radiometric and housekeeping measurements every 16 seconds. There are 20 radiometric measurements every 16 seconds, while the frequency of housekeeping measurements is either 1, 2, or 4 measurements per 16 seconds, depending on the type of measurement.

Telemetry data from the ERBE instruments on the NOAA-9 and NOAA-10 spacecraft are transmitted to Control and Data Acquisition (CDA) ground stations at Gilmore Creek, Alaska, and Wallops Island, Virginia that relay the data through a geostationary communications satellite to the SOCC at NESDIS in Suitland, Maryland. NOAA provides decommutation processing of the telemetry data and provides the data to LaRC. During portions of the ERBE mission, telemetry data from the NOAA spacecraft were transmitted to GSFC for decommutation processing and delivery to LaRC. Telemetry and tracking data from the ERBE instrument on ERBS are transmitted to the NASA ground terminal at White Sands, New Mexico through the Tracking and Data Relay Satellite System (TDRSS). The data are transmitted from the ground terminal to the



NASA communications center at GSFC, where the data are processed by the Information Processing Division (IPD) that provides ERBE data to LaRC.

6. Observations:

Data Notes:

Data notes are currently unavailable.

Field Notes:

Field notes are currently unavailable.

7. Data Description:

Spatial Characteristics:

Spatial Coverage:

The spatial coverage differs with the channel and the spacecraft, as described below.

WFOV Instruments: these two fixed detectors continuously view the earth disc (plus a small ring of space). The measurements are continuous over the entire globe for NOAA-9 and NOAA-10, and between 57 degrees north and south latitudes for ERBS which precesses approximately 3.95 degrees west per day.

MFOV Instruments: these two fixed detectors continuously view an area about 1000 km in diameter (nominally, a 5 degree earth central angle at the top of the Earth atmosphere, TOA). The measurements are continuous over the entire globe for NOAA-9 and NOAA-10, and between 57 degrees north and south latitude for ERBS.

Scanner Instruments: these three scanning instruments continuously view small areas over the entire Earth. The cross-track scan FOV is approximately 40 km at nadir, and there is a 35 FOV overlap at nadir for ERBS between scans.

ERBE scanner instruments on board the NOAA-9 and NOAA-10 satellites provide global coverage, while the ERBE scanner instrument onboard ERBS provides coverage between 67.5 degrees north and south latitude.

Spatial Coverage Map:

Though a map is not available, the limits of coverage are discussed in the Spatial Coverage Section.

Spatial Resolution:

The spatial resolution differs with the four types of instruments and the two types of spacecraft (ERBS and NOAA). The WFOV instruments have 136-degree FOV on ERBS and 126-degree FOV on the NOAA satellites. The MFOV instruments have footprints of approximately 5 geocentric degree radius or 1000 km at the TOA. The scanner instruments have an instantaneous hexagonal FOV with an angular size of 3 x 4.5 degree, which is equivalent to a 31 x 47 km footprint at nadir for ERBS and 44 x 65 km for NOAA. The solar instrument has an unencumbered FOV which observes the entire solar disk.

Gridded products of the scanner data are available in 2.5 x 2.5 degree resolutions. S-4 and S-4G scanner data are also available as 5 x 5 degree and 10 x 10 degree nested grids. The 5 x 5 degree resolution and 10 x 10 degree nested grids are available for numerical filter nonscanner data, and the 10 x 10 degree resolution is available for the shape factor nonscanner data on the S-4 output product.

Projection:

Gridding is an equal-angle projection of 2.5 x 2.5 degree (NFOV, 10368 bins), 5.0 x 5.0 degree (MFOV, 2592 bins), and 10.0 x 10.0 degree (WFOV, 648 bins).

Grid Description:

Binning of the data is based on an equal-angle grid of 2.5 x 2.5 degree (NFOV, 10368 bins), 5.0 x 5.0 degree (MFOV, 2592 bins), and 10.0 x 10.0 degree (WFOV, 648 bins). In each resolution, the bin number 1 is found at 90 degree N, 180 degree W with the bin number increasing in an easterly direction.



Temporal Characteristics:

Temporal Coverage:

Instruments on the three satellites (ERBS, NOAA-9, and NOAA-10) began acquiring Earth viewing data in November 1984, February 1985, and October 1986, respectively. All of the scanner instruments outlived their life expectancy of one year. The NOAA-9 scanner ceased operations on January 20, 1987 and the NOAA-10 scanner on May 22, 1989. The ERBS scanner ceased operations on February 28, 1990. All of the Earth-viewing nonscanner instruments collect measurements continuously except during calibrations. The solar instrument collects about 20 minutes of usable data during bi-weekly solar calibration periods.

Temporal Coverage Map:

A map is not available.

Temporal Resolution:

Each data granule consists of one day's worth of data that were collected by instruments from one of the three satellites (ERBS, NOAA-9, NOAA-10).

Data Characteristics:

Parameter/Variable:

The MWDT contains information from the WFOV and MFOV channels of the nonscanner instrument package. TOA estimates contained on the MWDT are calculated with the Inversion Subsystem deadscanner software (see MWDT(55-62) in Variable Description/Definition Section). The MWDT consists of a single file which contains various header information and daily data arranged chronologically. They may be data for up to 31 days on one S-7. All information on the S-7 is from the same satellite. There may exist up to three S-7s for the same month, one for each ERBE satellite.

The data period for the daily MWDT data starts at Greenwich midnight (zero Universal Time) and continues for 24 hours. This period is divided into 16-second intervals, hence, there are a maximum of 5400 data records per day. If there are periods with no data (data dropout), there will be less than 5400 data records. As long as there is one valid nonscanner measurement within a 16-second interval, a full data record is written, and default values are used to flag invalid data.

Each data records contains 75 elements (see Table 1). Each of the elements is described in the Variable Description/Definition section. The elements are offset and scale by the equation:

Integer Scaled Value = (Real Value + Offset) times (Scale Factor)

and are packed into a 1440-bit record (15 32-bit words and 60 16-bit words).

Table 3 describes each item in a MWDT data record. The first column is the data item number. The parameter description and units are listed for each item, followed by a scale factor column and an offset column. The next column lists the number of data item values in the record. The final columns list the number of bits in each data item and the total bits for each item in the record.

Table 3. MWDT Data Record Content

Item No.	Description	Units	Scale Factor	Offset	No. of Values per 16-sec	Bits per Value	Bits per 16-sec
1	Julian date	day	1	0	1	32	32
2	Julian time	day	109	0	1	32	32
3	Earth-sun distance	AU	109	0	1	32	32
4-5	Spacecraft position, x	m	1	0	2	32	64
6-7	Spacecraft position, y	m	1	0	2	32	64
8-9	Spacecraft, position, z	m	1	0	2	32	64
10-11	Spacecraft velocity, x-axis	m sec ⁻¹	1	0	2	32	64
12-13	Spacecraft velocity, y-axis	m sec ⁻¹	1	0	2	32	64
14-15	Spacecraft velocity, z-axis	m sec ⁻¹	1	0	2	32	64
16-17	Spacecraft nadir	deg	180	0	2	16	32



	position, colatitude						
18-19	Spacecraft nadir position, longitude	deg	100	-180	2	16	32
20	Sun position, colatitude	deg	100	0	1	16	16
21	Sun position, longitude	deg	100	-180	1	16	16
22	Orbit number key	---	1	0	1	16	16
23-26	WFOV, radiometric data, total	Wm ⁻²	10	0	4	16	64
27-30	WFOV, radiometric data, SW	Wm ⁻²	10	0	4	16	64
31-34	MFOV, radiometric data, total	Wm ⁻²	10	0	4	16	64
35-38	MFOV, radiometric data, SW	Wm ⁻²	10	0	4	16	64
39-42	WFOV, unfiltered, SW	Wm ⁻²	10	0	4	16	64
43-46	WFOV, unfiltered, LW	Wm ⁻²	10	0	4	16	64
47-50	MFOV, unfiltered, SW	Wm ⁻²	10	0	4	16	64
51-54	MFOV, unfiltered, LW	Wm ⁻²	10	0	4	16	64
55	WFOV, TOA est., NF, SW *	Wm ⁻²	10	0	1	16	16
56	WFOV, TOA est., NF, LW *	Wm ⁻²	10	0	1	16	16
57	MFOV, TOA est., NF, SW *	Wm ⁻²	10	0	1	16	16
58	MFOV, TOA est., NF, LW *	Wm ⁻²	10	0	1	16	16
59	WFOV, TOA est., SF, SW *	Wm ⁻²	10	0	1	16	16
60	WFOV, TOA est., SF, LW *	Wm ⁻²	10	0	1	16	16
61	MFOV, TOA est., SF, SW *	Wm ⁻²	10	0	1	16	16
62	MFOV, TOA est., SF, LW *	Wm ⁻²	10	0	1	16	16
63-66	Nonscanner, FOV, colatitude	deg	100	0	4	16	64
67-70	Nonscanner, FOV, longitude	deg	100	-180	4	16	64
71-72	Nonscanner operations mode flag	---	1	0	2	16	32
73	Nonscanner, TOA est., flag	---	1	0	1	16	16
74	Orbit number scale factor	---	1	0	1	16	16
Subtotal							1424
75	Spare	---	---	---	1	16	16



Total bits/16-sec record	1440
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* TOA estimates are taken to be at the center of the 32-second nonscanner average measurement interval.

There are nominally 5400 16-second records (24 hours) contained in a MWDT daily data set. Data dropout may reduce this number. There are a total of 1440 bits in a data record. The data records are arranged in groups as follows:

No. of Bits per Word	No. of Words	Bits	Cumulative Total Bits	Default Value (no data)
32	15	480	480	$2^{31}-1$
16	60	960	1440	$2^{15}-1$

If no data exists for a MWDT element, then the default value is set as all bits "on." **Scale factors and offsets should not be applied to the default values.**

Negative numbers are represented in two's complement notation. If negatives are read by a computer with word size larger than 16 bits, some sign extension logic must be applied.

Users with 32-bit machines with UNIX operating systems can use the code in Appendix B of the ERBE S-7 User's Guide to read and unpack the MWDT. Example output produced by the sample FORTRAN code is contained in Appendix C of the ERBE S-7 User's Guide for reference. Other users should use a similar user-written utility to unpack the data.

Variable Description/Definition:

[Table 3](#) describes each item in a MWDT data record. Each data item in a MWDT record is defined. Each definition begins with the MWDT index (1 <= index <= 75) and the parameter name. This heading is followed by a brief description of the parameter. The range of possible values is denoted by brackets. Some definitions are followed by notes which list more detailed information about the data item.

MWDT(1) - Julian Day. The Julian day is the whole part of the Julian date at the beginning of each 16-second MWDT record (days). [2440000 - 2460000]

MWDT(2) - Julian Time. The Julian time is the fractional part of the Julian date at the beginning of each 16-second MWDT record (days). [0.0 <= Julian time < 1.0]

NOTE: A new day begins with a Julian time of 0.5. A full 24-hour MWDT file starts with a Julian time given by $0.5 \leq \text{Julian time} < 0.5 + 16/86400$. Likewise, the last time will be $0.5 - 16/86400 \leq \text{Julian time} < 0.5$.

MWDT(3) - Earth-Sun distance. This is the approximate Earth-sun distance during the MWDT record in astronomical units (AU). [0.98 - 1.02]

This distance is updated every 60 seconds from ephemeris data.

MWDT(4-5) - S/C position, x. These elements contain the x positions of the spacecraft at the beginning (MWDT(4)) and end (MWDT(5)) of the 16-second MWDT record in the Earth equatorial-Greenwich coordinate system (m).

NOTE: The Earth equatorial-Greenwich coordinate system is an Earth-fixed, geocentric, rotating coordinate system with the x-axis in the equatorial plane through the Greenwich meridian, the y-axis lies in the equatorial plane 90 degrees to the east of the x-axis, and the z-axis is toward the North Pole.

The inertial position and velocity of the spacecraft is known every 60 seconds from ephemeris data. The ephemeris data nearest to the beginning record time is used to determine the Keplerian orbital elements which are evaluated at the desired record times. These inertial positions are then transformed into the rotating, Earth-fixed coordinate system at the appropriate time.

MWDT(6-7) - S/C position, y. These are the y positions of the spacecraft at the beginning (MWDT(6)) and end (MWDT(7)) of the 16-second MWDT record in the Earth equatorial-Greenwich coordinate system (m). See MWDT(4-5) NOTE.

MWDT(8-9) - S/C position, z. These are the z positions of the spacecraft at the beginning (MWDT(8)) and end (MWDT(9)) of the 16-second MWDT record in the Earth equatorial-Greenwich coordinate system (m). See MWDT(4-5) NOTE.

MWDT(10-11) - S/C velocity, x-axis. These are the inertial velocities of the spacecraft along the x-axis at the beginning (MWDT(10)) and end (MWDT(11)) of the 16-second MWDT record in the Earth equatorial-Greenwich coordinate system (m/sec). See MWDT(4-5) NOTE.

NOTE: The inertial velocity is determined from the Keplerian orbital elements and its three components are transformed into the rotating, Earth-fixed coordinate system. However, this inertial velocity is not adjusted to reflect the rotational velocity of the Earth-fixed coordinate system.

MWDT(12-13) - S/C velocity, y-axis. These are the inertial velocities of the spacecraft along the y-axis at the beginning (MWDT(12)) and end

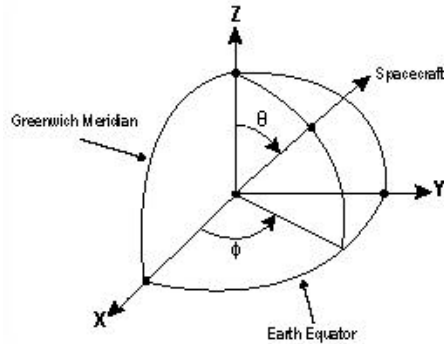
(MWDT(13)) of the 16-second MWDT record in the Earth equatorial-Greenwich coordinate system (m/sec). See MWDT(4) and MWDT(10) NOTES.

MWDT(14-15) - S/C velocity, z-axis. These are the inertial velocities of the spacecraft along the z-axis at the beginning (MWDT(14)) and end (MWDT(15)) of the 16-second MWDT record in the Earth equatorial-Greenwich coordinate system (m/sec). See MWDT(4) and MWDT(10) NOTES.

MWDT(16-17) - S/C nadir, colatitude. These are the colatitudes of the spacecraft at the beginning (MWDT(16)) and end (MWDT(17)) of the 16-second MWDT record in the Earth equatorial-Greenwich coordinate system (deg). [0 - 180]

NOTE: The colatitude and longitude of the spacecraft at the beginning of the MWDT record are determined as follows:

The position of the spacecraft is:



MWDT(18-19) - S/C nadir, longitude. These are the longitudes of the spacecraft at the beginning (MWDT(18)) and end (MWDT(19)) of the 16-second MWDT record in the Earth equatorial-Greenwich coordinate system (deg). [0 - 360] See MWDT(16) NOTE.

MWDT(20) - Sun position, colatitude. This is the colatitude of the sun at the beginning of the MWDT record in the Earth equatorial-Greenwich coordinate system (deg.). [0 - 180]

MWDT(21) - Sun position, longitude. This is the longitude of the sun at the beginning of the MWDT record in the Earth equatorial-Greenwich coordinate system (deg.). [0 - 360]

MDWDT(22) - Orbit number key. The orbit number key is a value used with the orbit number scale factor, MWDT(74), to determine the orbit number. The orbit number is an index of the spacecraft revolutions about the Earth. It increases by 1 at the ascending node or when the spacecraft passes from the southern hemisphere to the northern hemisphere. It is a relative measure since orbit number 1 may not correspond to the first revolution about the Earth. The orbit number is from the orbital ephemeris data provided by Goddard Space Flight Center (GSFC). The orbit number is equal to the **orbit number key plus (the orbit number scale factor times 32000)**.

MWDT(23-38) - Filtered nonscanner measurements. These are filtered measurements at satellite altitude (Wm^{-2}). They are divided into the following categories:

MWDT(23-26)--WFOV, radiometric, total
 MWDT(27-30)--WFOV, radiometric, shortwave
 MWDT(31-34)--MFOV, radiometric, total
 MWDT(35-38)--MFOV, radiometric, shortwave

NOTE 1: Each value is an average over 4 seconds of a 16-second time period.

NOTE 2: Nonscanner geometry and radiometric measurements are recorded on the PAT every 0.8 seconds so that there are 20 such entries per 16-sec PAT record.

MWDT(39-54) - Unfiltered measurements. These are the unfiltered measurements at satellite altitude. The SW measurements are set equal to zero when the entire FOV is in darkness (Wm^{-2}). These measurements are divided into the following categories:

MWDT(39-42)--WFOV, unfiltered, shortwave
 MWDT(43-46)--WFOV, unfiltered, longwave
 MWDT(47-50)--MFOV, unfiltered, shortwave
 MWDT(51-54)--MFOV, unfiltered, longwave

The unfiltered measurements m^i are estimated from the filtered measurements M_F^i (see MWDT(23)) by:

$$m^{SW} = m_F^{SW} - 0^{SW}$$

$$m^{LW} = m_F^{TOT} - m_F^{SW}$$



where 0^{SW} is a shortwave offset that is either zero or the average nighttime shortwave measurements for the previous nighttime passage. 0^{SW} is updated each satellite revolution or as often as 15 times for a 24-hour period.

The unfiltered nonscanner measurements are recorded on the MWDT every 4 seconds so that there are four measurements per 16-second record. For more information, see the Processed Archival Tape S-8 PAT User's Guide ([Reference 4](#)) and the Merge Subsystem and Inversion Subsystem Reference Manuals ([Reference 5](#) and [Reference 6](#), respectively).

MWDT(55-62) - TOA estimates of radiant flux. These are estimates of the flux (SW or LW) at the top-of-atmosphere (Wm^{-2}). TOA estimates are based on nonscanner unfiltered measurements averaged over 32 seconds. All TOA estimates contained on the S-7 product are independent of the actual underlying scene type. The TOA estimates on S-7 differ from the TOA estimates on the S-8 PAT tape. The S-8 estimates use scanner derived scene information to invert the nonscanner measurements. The S-7 does not. The S-7 estimates assume the scene is mostly-cloudy over ocean everywhere. Obviously, this is not the case, but when scanner scene data are not used, mostly- cloudy over ocean is the best single scene to use. Since the S-7 is a nonscanner product and produces TOA estimates long after the scanners cease to operate, the scanner information is not used. Using a single scene type to derive the numerical filter and shape factors is felt to improve the long-term consistency of the TOA estimates.

The TOA estimates are divided into the following categories:

MWDT(55)--WFOV, NF, SW
 MWDT(56)--WFOV, NF, LW
 MWDT(57)--MFOV, NF, SW
 MWDT(58)--MFOV, NF, LW
 MWDT(59)--WFOV, SF, SW
 MWDT(60)--WFOV, SF, LW
 MWDT(61)--MFOV, SF, SW
 MWDT(62)--MFOV, SF, LW

NF is the Numerical filter method--used to determine 5-degree regional averages. **SF** is the Shape factor method--used to determine 10-degree regional averages.

NOTE 1: The numerical filter uses a sequence of 13 average nonscanner measurements \bar{m}_j to derive an estimate of radiant flux \hat{M} at the TOA. Each average measurement combines 32 seconds of nonscanner unfiltered measurements. Thus, a single estimate is affected by measurements over a 416-second time interval or 26 PAT records. The number filter estimate is given by:

$$\hat{M}^i = \sum_{j=-6}^6 w_j^i \bar{m}_j^i$$

i = shortwave, longwave

where the 13 inversion weights w_j are a function of the mostly-cloudy over ocean bidirectional model for shortwave and are empirically derived spacecraft dependent constants for longwave.

NOTE 2: The shape factor technique inverts a single average measurement \bar{m} to derive the estimate of radiant flux \hat{M} at the TOA. The average measurement combines 32 seconds of nonscanner unfiltered measurements. The shape factor estimate is given by:

$$\hat{M}^i = \frac{\bar{m}^i}{SF^i} + B^i$$

i = shortwave, longwave

For longwave, the MFOV and WFOV shape factors are constants. For shortwave, the parameters SF and B are obtained in one of three ways.

The first way of obtaining shortwave inversion parameters is to set $B = 0$ and to calculate SF by assuming that the albedo is constant over the FOV. The shortwave shape factor is a function of the mostly-cloudy over ocean shortwave bidirectional model.

The second way of obtaining shortwave inversion parameters is to set $B = 0$ and to use constants sets of empirically derived spacecraft dependent MFOV and WFOV shape factors based on the mostly-cloudy over ocean bidirectional model and as a function of the solar zenith angle.

The first and second approach give very similar results. The slight difference is due to linear interpolation in solar zenith angle and altitude for method two.

The third way of obtaining the shortwave inversion parameters is to define B and SF as regression coefficients based on a simulation study. These parameters are given by:

$SF^{SW} = \text{function of solar zenith at nadir}$

$B^{SW} = \text{function of solar zenith at nadir}$



See the nonscanner TOA estimate flag, MWDT(73) to determine which approach is used.

MWDT(63-66) - FOV, colatitude. These are the colatitudes for the 4-sec average radiometric nonscanner measurements in the Earth equatorial-Greenwich coordinate system (deg). [0 - 180]. See MWDT(23-38) NOTES 1 and 2).

NOTE: 4-sec nonscanner geometric and radiometric data are based on up to five individual measurement sets. FOV position data are for the centermost of the these data sets if available on the PAT; otherwise, the position is as close to the 4-sec center as is available on the PAT.

MWDT(67-70) - FOV, longitude. These are the longitudes for the 4-sec average radiometric nonscanner measurements in the Earth equatorial-Greenwich coordinate system (deg). [0 - 360]. See MWDT(23-38) NOTES 1 and 2 and MWDT(63-66) NOTE.

MWDT(71-72) - Nonscanner operations flag word. This is a record level flag which defines the nonscanner condition over a 16-second interval. Each bit of this 2-word flag is defined in Table 4:

Table 4. MWDT Flag Words, Nonscanner Operations

Bit Position (Right to Left)	Bit Value	Meaning
Word 1		
0	0	Instrument power in ON
	1	Instrument power in OFF
1-2	00	Calculating solar monitor and Earth-viewing vectors
	01	Calculating solar monitor-viewing vectors only
	10, 11	Not calculating view vectors
3	0	No telemetry data drop out
	1	Telemetry data drop out due to:
		a) Previous record missing;
		b) Nonscanner instrument disabled on previous record; or
		c) Nonscanner command echo bad on previous record
4-5	00	No new command
	01	New command
	10, 11	Not defined, or a new command not understandable
6	0	New mode command
	1	No new mode command
7-8	00	First record after end of solar calibration sequence
	01	First record after end of internal calibration sequence
	10, 11	None of the above
9	0	In solar calibration sequence
	1	Not in solar calibration sequence or status unknown
10	0	In internal calibration sequence
	1	Not in internal calibration sequence or status unknown
11-12	The last instrument elevation command is given below:	
	00	Go to nadir (Earth-view)
	01	Go to solar ports (non Earth-view)
	10	Go to internal sources (non Earth-view)
	11	The last elevation command is undefined
13-14	---	Spare bits
15	0	At least one nonscanner 4-second average radiometric value MWDT(23-38) has both a good radiometric flag and a good FOV flag



		(see MWDT(71) NOTE).
	1	The above situation does not exist
Word 2		
0-2	The last shortwave internal calibration source command is given below:	
	000	Turn power OFF
	001	Go to power level 1
	010	Go to power level 2
	011	Go to power level 3
	100,101,110,111	The last SWICS comand is undefined
3-4	The last solar monitor shutter command is given below:	
	00	Open shutter
	01	Close shutter
	10,11	The last shutter command is undefined
5-6	The last WFOV blackbody heater command is given below. Positions 1 and 2 are stored temperatures.	
	00	Turn heater OFF
	01	Go to temperature 1
	10	Go to temperature 2
	11	The last heater command is undefined
7-8	The last MFOV blackbody heater command is given below. Positions 1 and 2 are stored temperatures.	
	00	Turn heater power OFF
	01	Go to temperature 1
	10	Go to temperature 2
	11	The last heater command is undefined
9-10	The azimuth position during solar calibration is given below. A is a stored azimuth value.	
	00	Azimuth at position A
	01	Azimuth not at position A
	10,11	Position of azimuth undefined
11-15	---	Spare bits

NOTE: If MWDT(71) is positive (see bit position 15), then at least one of the 4-second average radiometric values on this record is good, and the associated field-of-view flag (not contained on this product) was determined to be good during processing by the Inversion Subsystem deadscanner software. If the record contains no good 4-second average radiometric values (radiometric flag, field-of-view flag, or both, are bad for each 4-second average radiometric value), MWDT(71) is set negative during Inversion Subsystem deadscanner processing, and the record will not appear on the S-7 product.

MWDT(73) - Nonscanner, TOA estimate flag. The nonscanner TOA estimates occur every 32 seconds and are recorded every 16 seconds on the MWDT product. Thus, the same estimate will appear on two consecutive MWDT records where the location of the estimate is the end of the first record and the beginning of the second record. This information along with the specific shortwave shape factor technique (see MWDT(55) NOTE 2) is recorded in this flag as defined below (X denotes any value):

Bit Value	Description
XXXXXXXX0	All nonscanner estimates MWDT(55-62) are located at the beginning of the record at MWDT(16) and MWDT(18)
XXXXXXXX1	All nonscanner estimates MWDT(55-62) are located at the end of the record at MWDT(17) and MWDT(19)
XXXXX00X	The nonscanner shortwave shape factor estimates MWDT(59 and 61) were derived using the first approach. (See shape factor comment under MWDT(55-62) NOTES)
XXXXX01X	The nonscanner shortwave shape factor estimates MWDT(59 and 61) were derived using the second approach. (See shape factor comment under MWDT(55-62) NOTES)
XXXXX10X	The nonscanner shortwave shape factor estimates MWDT(59 and 61) were derived using the third approach. (See shape factor comment under MWDT(55-62) NOTES)



MWDT(74) - Orbit number scale factor. This scale factor is multiplied by 32000 and added to the orbit number key, MWDT(22), to compute the orbit number (see MWDT(22)).

MWDT(75) - Spare. This is a spare and is not used.

Unit of Measurement:

Units of measurement for the calculated and measured science variables for the S-7 data product can be found in the Variable Description/Definition Section of this document.

Data Source:

Please refer to the Summary of Parameters Section of this document.

Data Range:

...

Sample Data Record:

ERBE data records are quite large (on the order of 104 or 105 binary bytes per record). Reproducing sample records of this size in a document of this sort is impractical.

8. Data Organization:

Data Granularity:

A general description of data granularity as it applies to the IMS appears in the [EOSDIS Glossary](#).

Data Format:

Each S-7 product contains four header records (the standard ERBE header record, a daily record count header record, the scale factor header record, and the offsets header record) and from 1 to 31 daily data sets. Each of the daily data sets contains up to 5400 records of MFOV and WFOV data.

Standard ERBE Header Record. The first record on the MWDT contains the standard ERBE header record which identifies the data on the file and serves as an identification number for any correspondence between a user and the ERBE Data Management Team. It is a 30-byte record formatted as 8-bit bytes and is defined in Table 5. Since the S-7 is a monthly product, the beginning Julian date on the header corresponds to 0000 hours UT for the first day of the month, even if data for the first day is unavailable.

Table 5. Standard ERBE Header Record

Bytes	Position	Value	Interpretation
1-2	Subsystem Indicator	1-7	The subsystem outputting the data product is: 1 - Telemetry 2 - Ephemeris 3 - Attitude 4 - Merge/FOV/Count Conversion 5 - Inversion 6 - Daily Data Base & Monthly Time/Space Averaging 7 - Output Products
3-4	Product Code	1-9	Each subsystem assigns its output (tape, disc, paper, plot, etc.) a unique number for identification. (Reference 3)
5-6	Spacecraft Indicator	1-7	The data is from the following combination of spacecrafts: 1 - NOAA-9 only 2 - ERBS only 3 - NOAA-10 only 4 - NOAA-9 and NOAA-10 5 - NOAA-9 and ERBS 6 - NOAA-10 and ERBS

			7 - NOAA-9 and NOAA-10 and ERBS
7-8	Whole Julian date (high-order part)	e.g.,244	Leftmost 3 digits of the 7-digit whole part of the initial Julian date
9-10	Whole Julian date (low-order part)	e.g.,5700	Rightmost 4 digits of the 7-digit whole part of the initial Julian date
11-12	Fractional Julian date	e.g.,5000	First 4 digits of the fractional part of the initial Julian date times 10000
13-14	Processed Version Counter	1-99	A counter initially set to 1 and incremented by one each time the product is reprocessed
15-16	Year Processed	e.g.,84	The last two digits of the year of process date. The process date is the date (local time) when the data product was processed (or reprocessed) at Langley Research Center, Hampton, VA
17-18	Month Processed	12	Month of the process date. January is 1 and December is 12
19-20	Day Processed	1-31	Day of the process date
21-22	Hour Processed	0-23	Hour of the process date
23-24	Minute Processed	0-59	Minute of the process date
25-26	Second Processed	0-59	Second of the process date
27-30	Spares	0	Zero-filled spares to product a record which is a multiple of 8-, 16-, and 60-bits

An example of the information in this header for the MWDT is given in Table 6.

Table 6. Example of MWDT's ERBE Header Record

Bytes	Description	Example	Note
1-2	Subsystem Indicator	5	The MWDT is output from the Inversion Subsystem and will always have a 5 as the subsystem indicator.
3-4	Product Code	9	The Inversion Subsystem has arbitrarily defined the product code for the monthly MWDT as 9.
5-6	Spacecraft Indicator	2	Since the MWDT is for a single spacecraft, only a 1, 2, or 3 is appropriate here.
7-8	Whole Julian date (high-order part)	244	The initial Julian date, for example, is 2445700.5000 which corresponds to Greenwich midnight beginning January 1, 1984.
9-10	Whole Julian date (low-order part)	5700	The whole Julian date changes at Greenwich noon.
11-12	Fractional Julian date	5000	Since the first 24-hour period of a MWDT file starts at Greenwich midnight, the fractional initial Julian date will be 0.5.
13-14	Processed Version Counter	1	A value of 1 means that the MWDT has been processed one time and not reprocessed.
15-16	Year Processed	84	For this example, the MWDT was processed on February 3, 1984 at 9 P.M. 48 ^M 54 ^S .
17-18	Month Processed	2	
19-20	Day Processed	3	



21-22	Hour Processed	21	
23-24	Minute Processed	48	
25-26	Second Processed	54	
27-30	Spares	0	

Daily Record Count Record. The second record on the S-7 contains the record counts for the daily data sets. It is a 720-bit record formatted in 45 16-bit words. The first 31 words contain the number of data records per day for days 1 through 31, respectively. The last 14 words are spares. The daily record counts can be used to calculate the byte address for any data element ([see Table 3](#)).

Scale Factor and Offset Records. The third and fourth records of the S-7 contain the scale factors and offsets, respectively. These records have 75 elements each. They are ordered to correspond with the MWDT data elements. Each record contains 1440 bits which are divided into 32- and 16-bit words. Since the scale factors and offsets are integers, they require no scaling and are used to scale the integer data values.

The scale factors and offsets are nominal values. **The actual values used to scale the data are those recorded on the MWDT in the third and fourth records.**

9. Data Manipulations:

Formulae:

Derivation Techniques and Algorithms:

Data Processing Sequence:

Processing Steps:

The Langley Research Center (LaRC) has the responsibility of processing and validating all science data from the ERBE mission and of distributing the resulting data products to the science community. The ERBE data processing system at LaRC uses a modular software subsystems approach to process the ERBE data, starting with the input telemetry and ephemeris data from Goddard Space Flight Center (GSFC) and NOAA and ending with the production of the required science data products.

The diagram in [the Flowchart Figure](#) shows the major steps in the science data processing, together with the primary input and output data products. The first step in this processing procedure is to ingest 24 hours of telemetry data from the ERBS, NOAA-9, or NOAA-10 spacecraft into the front-end processing subsystem of the Data Processing System. The processing at this step accounts for spacecraft differences and for differences in the data acquisition and handling systems of the ERBS and TIROS N satellites. The data are organized into a format that is common to data from GSFC and NOAA. Extensive data quality editing and evaluation are performed, including the checking of quality flags appended by the tracking networks and processing systems at GSFC and NOAA. The operational status of the instruments is determined, and all instrument housekeeping data and selected spacecraft housekeeping measurements are converted to engineering units and edited. Pointing vectors for the optical axes of the detectors are calculated in a local horizon coordinate system at the spacecraft.

The 8-day ephemeris data sets are processed and validated separately before combining them with the corresponding telemetry data. Orbital data are tested for consistency with data from the previous week, and tests are performed to verify the consistency of the orbit calculations between 1-minute data points. The tests include checks for in-plane and out-of-plane consistency and precision. The routine verification processing and other analyses performed to verify the accuracy of the ephemeris data have generally demonstrated accurate orbit determination for both the ERBS and NOAA spacecraft.

The next major processing stage begins with the merging of the output data from telemetry processing with data output from the ephemeris processing. The FOV locations on a surface at the TOA are determined for every radiometric measurement. The FOV locations are more critical for the scanner measurements than those of the nonscanner because of the small FOV of the scanner instrument. A FOV accuracy analysis has shown that the calculated locations of the scanner measurements are well within the FOV footprint of the instrument on the Earth.

At this processing stage, the raw measurements for each radiometric detector are also converted to incident radiances at the spacecraft. The conversion algorithms employ calibration coefficients that are based primarily on ground-based calibration data, but which are updated with results from in-flight calibrations.

In the inversion processing stage, data from the scanner detectors are used to identify the type of scene or source at the TOA that produced the raw radiometric measurements. Based on the scene type and geographical location, the scanner measurements are adjusted to account for changes in the spectral response in each detector. Using the selected scene-type, one of several angular directional models is selected for inverting or reducing the measurements from satellite altitude to radiant fluxes at the TOA. The nonscanner measurements are inverted using scene information determined during scanner data processing and two different inversion algorithms. One algorithm employs geometric shape factors and the other employs numerical filtering. An archival product, called the Processed Archival Tape (PAT), is produced at this point to retain detailed time histories of estimates of the radiant fluxes at the TOA.

The time-ordered estimates of TOA fluxes are sorted into spatial sequences for both the scanner and nonscanner measurements, grouping all estimates for a month together on a regional basis. A full calendar month of estimates is then retrieved for each region of the Earth. Hourly,



daily, and monthly estimates of several different parameters are derived by interpolation using directional models that describe the temporal variation of the radiation budget components. Archival products of monthly averages of radiation components for both the scanner and nonscanner are produced at this point.

Several archival products are produced at the [final stage of data processing](#). The nested averages product gives values of the scanner and nonscanner fluxes from each instrument averaged over various spatial scales. The processing at this stage also combines data from all available spacecraft to produce a combined- satellite product of TOA fluxes averaged over the same spatial scales. An archival product for solar monitor measurements is also produced to provide time histories of solar calibration data. Finally, a scene validation product is produced that combines ERBE data with measurements from the AVHRR and the HIRS instruments. Data from these two NOAA instruments are used to validate the scene identification algorithm. Currently all archival data products are distributed first to the ERBE Science Team for review and validation and then to LaRC ASDC for archival.

Processing Changes:

There are no plans for reprocessing.

Calculations:

Special Corrections/Adjustments:

...

Calculated Variables:

Please refer to the Variable Description/Definition Section of this document.

Graphs and Plots:

There are no graphs/plots available.

10. Errors:

Sources of Error:

A discussion of various factors that may lead to errors are discussed in the Confidence Level/Accuracy Judgement Section of this document.

Quality Assessment:

Data Validation by Source:

The measurement of radiation budget requires a massive data processing system. ERBE's system uses about 250,000 lines of FORTRAN code. This system also uses an additional 150,000 lines of off-line diagnostic work. The stringent requirements for accuracy in the budget dictate an acute attention to detail.

The ERBE data processing system uses about 25,000 coefficients. These coefficients are conveniently arranged in three groups. The first group is the set of "calibration coefficients" that appear in the algorithms converting telemetry counts to instrument irradiation. Ground- and in-flight-calibration sources provided these coefficients. The second group includes the angular distribution models (ADMs) and spectral unfiltering coefficients needed for inversion. A categorization of the Nimbus-7 ERB measurements forms the base for the ADM's. Missing bins were filled using the reciprocity principle. A combination of radiative transfer results and measurements of the instrument spectral responses provides the spectral correction coefficients. The third and final group of parameters consists of the coefficients needed for time averaging, mainly the directional models. These models describe the dependence of each scene type's albedo upon solar zenith angle. These directional models also came from the Nimbus-7 ERB, but have been suitably supplemented by Geostationary Operational Environmental Satellite (GOES) observations where needed. The majority of the coefficients come from the inversion process.

The earth's radiation budget is not easy to measure, even indirectly. The ERBE Science Team has relied on consistency and measurement intercomparisons for validation. Fortunately, ERBE data provides a number of these checks. The Science Team chose ten of these as validation criteria. These criteria provide a way of judging the consistency of the various parameters in the data processing system.

Confidence Level/Accuracy Judgement:

The ERBE data products are complex assemblages of data and models. Thus, their uncertainties are difficult to compute. The following numbers represent estimates of the standard deviations about a given data point within which the true measurement might lie. They are not definitive confidence intervals, but are intuitively based on the observed discrepancies in the intercomparisons. It is also important to remember that different measurements have different uncertainties. First, for instantaneous radiances, we expect uncertainties of about 10%



longwave observations of filtered radiance and 2 0.000000 or shortwave. Radiative transfer comparison and spectral consistency provide the basis for this uncertainty estimate. Second, on an instantaneous observation of flux from 2.5 x 2.5 degree geographic regions, the ERBS/NOAA-9 intercomparisons offer reasonable estimates of uncertainty. These are 5 Wm⁻² in the longwave and 15 Wm⁻² in the shortwave. Third, on a monthly average, regional basis, the uncertainties in the scanner data are about 5 Wm⁻² for shortwave and 5 Wm⁻² for longwave. These come from simulations with GOES data. This uncertainty represents no change from the preflight estimate. The nonscanner averages may be somewhat more uncertain because of sampling and diurnal averaging process. Fourth, the uncertainty in global, annual average net radiation is probably about 5 Wm⁻². This estimate is based on the imbalance obtained using scanner data from the four validation months (April, July, and October 1985; January 1986).

Measurement Error for Parameters:

A discussion of measurement error is found in the Confidence Level/Accuracy Judgement Section of this document.

Additional Quality Assessments:

None.

Data Verification by Data Center:

The data were received on 12 inch worm media. Before the data were archived, the ASDC checked all granules to ensure that the size of the granules matched that what was delivered on the media. The version number of the granules were also checked so that the most current version of the data are available to the user community. Granule level metadata were extracted from the granules such as the product ID, satellite(s) ID, and data date.

11. Notes:

Limitations of the Data:

There are no known limitations or unreliable aspects in the algorithms implemented to generate the ERBE science data.

Known Problems with the Data:

There are no known problems or inconsistencies in the ERBE data.

Usage Guidance:

A monthly product summary is currently produced for the PAT, and S-7 data, which includes an explanation of the data coverage for the month. In those rare instances when an archive tape is not produced, reasons and explanations for this are also included in the monthly summary report.

Any Other Relevant Information about the Study:

None.

12. Application of the Data Set:

Measurements of the radiation budget provide one of the important tools for the validation of numerical models of the atmosphere. They also provide possibilities for "climate experiments" by allowing the sensitivity of the radiation budget to various forcings to be studied empirically.

The use of cloud discrimination has provided a significant new source of information on the influence of clouds and the characteristics of clear-sky fluxes. This information is particularly important in understanding cloud forcing. It is also important in describing the response of clouds to climate change: the climate cloud sensitivity.

13. Future Modifications and Plans:

The ERBE project plans to complete the reprocessing, which is currently in progress, of the nonscanner data using inversion and time/space averaging processes which do not use scanner scene identification information.

Current plans are to reprocess the ERBE scanner data beginning in 1996 using the CERES algorithms.

To continue the measurements of the radiation budget, a second project, the Clouds and the Earth's Radiant Energy System (CERES), is currently being developed. CERES is a key component of the Earth Observing System (EOS). The CERES instruments are improved models of the Earth Radiation Budget Experiment (ERBE) scanner instruments. The strategy of flying instruments on Sun-synchronous, polar orbiting satellites, such as NOAA-9 and NOAA-10, simultaneously with instruments on satellites that have precessing orbits in lower inclinations, such as ERBS, was successfully developed in ERBE to reduce time sampling errors. CERES will continue that strategy by flying instruments on the

polar orbiting EOS platforms simultaneously with an instrument on the Tropical Rainfall Measuring Mission (TRMM) spacecraft, which has an orbital inclination of 35 degrees. In addition, to reduce the uncertainty in data interpretation and to improve the consistency between the cloud parameters and the radiation fields, CERES will include cloud imager data and other atmospheric parameters. The first CERES instrument is scheduled to be launched on the TRMM spacecraft in 1997. Additional CERES instruments will fly on the EOS-AM platforms, the first of which is scheduled for launch in 1998, and on the EOS-PM platforms, the first of which is scheduled for launch in 2000.

14. Software:

Software Description:

Read software is available for this data set.

Software Access:

The software can be obtained through the Langley ASDC. Please refer to the contact information below. The software can also be obtained at the same time the user is ordering this data set.

15. Data Access:

Contact Information:

Langley ASDC User and Data Services Office
NASA Langley Research Center
Mail Stop 157D
Hampton, Virginia 23681-2199
USA
Telephone: (757) 864-8656
FAX: (757) 864-8807
E-mail: support-asdc@earthdata.nasa.gov

Data Center Identification:

Langley ASDC User and Data Services Office
NASA Langley Research Center
Mail Stop 157D
Hampton, Virginia 23681-2199
USA
Telephone: (757) 864-8656
FAX: (757) 864-8807
E-mail: support-asdc@earthdata.nasa.gov

Procedures for Obtaining Data:

Data, programs for reading the data, and user's guides can be obtained through the EOSDIS Langley ASDC on-line system which will allow users to search through the data inventory and place orders on-line.

Langley ASDC User and Data Services Office
NASA Langley Research Center
Mail Stop 157D
Hampton, Virginia 23681-2199
USA
Telephone: (757) 864-8656
FAX: (757) 864-8807
E-mail: support-asdc@earthdata.nasa.gov
URL: <http://eosweb.larc.nasa.gov>

The Langley ASDC User and Data Services staff provides technical and operational support for users ordering data.

Data Center Status/Plans:

On a regular basis, individual ERBE data granules are reviewed by local members of the ERBE Science Team. Upon Science Team approval,



Distributed by the Atmospheric Science Data Center
<http://eosweb.larc.nasa.gov>



the ERBE Data Management Team releases the data granule to the LaRC ASDC for archive.

16. Output Products and Availability:

No additional output products are available for the ERBE S-7 data set.

17. References:

1. Kopia, L.P., 1986. "The Earth Radiation Budget Experiment Scanning Instrument," Reviews of Geophysics and Space Physics, 24, 400-406.
2. Luther, M.R., J.E. Cooper, and G.R. Taylor, 1986. "The Earth Radiation Budget Experiment Nonscanning Instrument," Reviews of Geophysics and Space Physics, 24, 391-399.
3. ERBE Data Management System Data Products Catalog, December 1986.
4. ERBE Data Management System Processed Archival Tape S-8 PAT User's Guide, December 1987.
5. ERBE Data Management System Reference Manual; Volume IV; Merge, FOV Calculations, and Count Conversion, August 1987.
6. ERBE Data Management System Reference Manual, Volumes Va and Vb, Inversion, August 1987.
7. ERBE Data Management System Raw Archival Tape S-1 RAT User's Guide, July 1985.
8. ERBE Data Management System Solar Incidence Tape S-2 User's Guide, July 1985.
9. ERBE Data Management System The Regional, Zonal, and Global Averages S-4 User's Guide, Revision 1, February 1993.
10. ERBE Data Management System The Regional, Zonal, and Global Gridded Averages S-4G User's Guide, Revision 1, February 1993.
11. ERBE Data Management System Earth Radiant Fluxes and Albedo, Scanner S-9, Nonscanner S-10 User's Guides, Revision 1, March 1993.
12. Smith, G.L., R.N. Green, E. Raschke, L.M. Avis, B.A. Wielicki, and R. Davies, 1986. "Inversion Methods for Satellite Studies of the Earth's Radiation Budget: Development of Algorithms for the ERBE Missions." Rev. of Geophys., 24:407-421.

18. Glossary of Terms:

[EOSDIS Glossary.](#)

Albedo

The ratio of shortwave radiant flux to the integrated solar incidence, where zero (0.0) represents total absorption, and one (1.0) represents total reflectance.

Nadir

That point on the celestial sphere vertically below the observer, or 180 degree from the zenith.

Radiance

The radiant flux per unit solid angle per unit of projected area of the source; usual unit is the Watt per square meter per steradian. Also known as steradiancy.

Radiant Flux

The time rate of flow of radiant energy. Usual unit is the Watt per square meter.

S-4: Regional, Zonal, and Global Averages Product

The S-4 contains averages of flux and albedo on regional, zonal, and global scales for both scanner and nonscanner data. For more information on this product please refer to the ERBE S-4 Data Set Document.

S-4N: Regional, Zonal, and Global Averages Product

The S-4N contains averages of flux and albedo on regional, zonal, and global scales for both scanner and nonscanner data. For more information on this product please refer to the ERBE S-4N Data Set Document.

S-4G: Regional, Zonal, and Global Gridded Averages Product

The S-4G contains averages of flux and albedo on regional, zonal, and global scales for both scanner and nonscanner data. The S-4G product is arranged by parameter value. For more information on this product please refer to the ERBE S-4GN Data Set Document.

S-4GN: Regional, Zonal, and Global Gridded Averages Product

The S-4GN contains averages of flux and albedo on regional, zonal, and global scales for nonscanner data. The S-4GN product is arranged by parameter value. For more information on this product please refer to the ERBE S-4G Data Set Document.

S-7: Medium-Wide Field-of-View Data Tape

The S-7 product contains a condensed version of the nonscanner data that are found in a monthly set of the S-8 product, **except** that the shortwave estimates of the radiant flux at the top-of-atmosphere (TOA) are based on the mostly-cloudy over ocean bidirectional



model. The S-7 product then provides a consistent data set of nonscanner TOA estimates which are not dependent on scene type and, therefore, not dependent on the operational status of the ERBE scanner instruments.

S-8: Processed Archival Tape

The S-8 contains ERBE scanner and nonscanner radiometric measurements for one day and one satellite. Estimates of the flux at the TOA based on these measurements are also included.

S-9: Earth Radiant Fluxes and Albedo for Month Scanner)

The S-9 contains regional hourly and daily monthly averages as well as the actual individual hour box data which is the input data to the Monthly Time/Space Averaging Subsystem.

S-10: Earth Radiant Fluxes and Albedo for Month (Nonscanner)

The S-10 contains regional hourly and daily monthly averages as well as the actual individual hour box data which are the input data to the Monthly Time/Space Averaging Subsystem. The S-10 contains numerical filter data of 5-degree resolution and shape factor data of 10-degree resolution from the nonscanner instrument.

S-10N: Earth Radiant Fluxes and Albedo for Month (Nonscanner)

The S-10N product contains the same science information arranged in the same order as the S-10; however, there are some differences in the processing algorithms and data format. The data set S-10N consists of nonscanner data processed without scene identification from the scanner and with numerical filter cross-track enhancement technique. For more information on this product please refer to the ERBE S-10N Data Set Document.

Zenith

That point on the celestial sphere vertically above the observer.

19. List of Acronyms:

[EOSDIS Acronyms.](#)

ASDC - Atmospheric Science Data Center

AU - Astronomical Unit

AVHRR - Advanced Very High Resolution Radiometer

CS - Clear-Sky

CERES - Clouds and Earth's Radiant Energy System

deg - degree

DAAC - Distributed Active Archive Center

EOR - End-of-Record

EOS - Earth Observing System

EOSDIS - Earth Observing System Data and Information System

ERBE - Earth Radiation Budget Experiment

ERBS - Earth Radiation Budget Satellite

FOV - Field-of-View

GSFC - Goddard Space Flight Center

HIRS - High-Resolution Infrared Radiometer Sounder

IMS - Information Management System

LaRC - Langley Research Center

LW - Longwave

m - meter

m/sec - meters/second

MFOV - Medium Field-of-View

MWDT - Medium-Wide Data Tape

NASA - National Aeronautics and Space Administration

NESDIS - National Environmental Satellite Data and Information Service

NF - Numerical Filter

NOAA - National Oceanic and Atmospheric Administration

NOAA-9 - National Oceanic and Atmospheric Administration Operational Weather Monitoring Satellite number 9

NOAA-10 - National Oceanic and Atmospheric Administration Operational Weather Monitoring Satellite number 10

NORAD - North American Aerospace Defense Command

PAT - Processed Archival Tape

POCC - Payload Operation and Control Center

RAT - Raw Archival Tape

SAGE - Stratospheric Aerosol and Gas Experiment

SF - Shape Factor

SOC - Satellite Operations and Control Center (NOAA)

SW - Shortwave

SWICS - Shortwave Internal Calibration Source

TDRSS - Tracking and Data Relay Satellite System

TIROS - Television Infrared Radiometer Orbiting Satellite

TOA - Top-of-Atmosphere

URL - Uniform Resource Locator

UT - Universal Time



WFOV - Wide Field-of-View
Wm⁻² - Watts per square meter

20. Document Information:

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